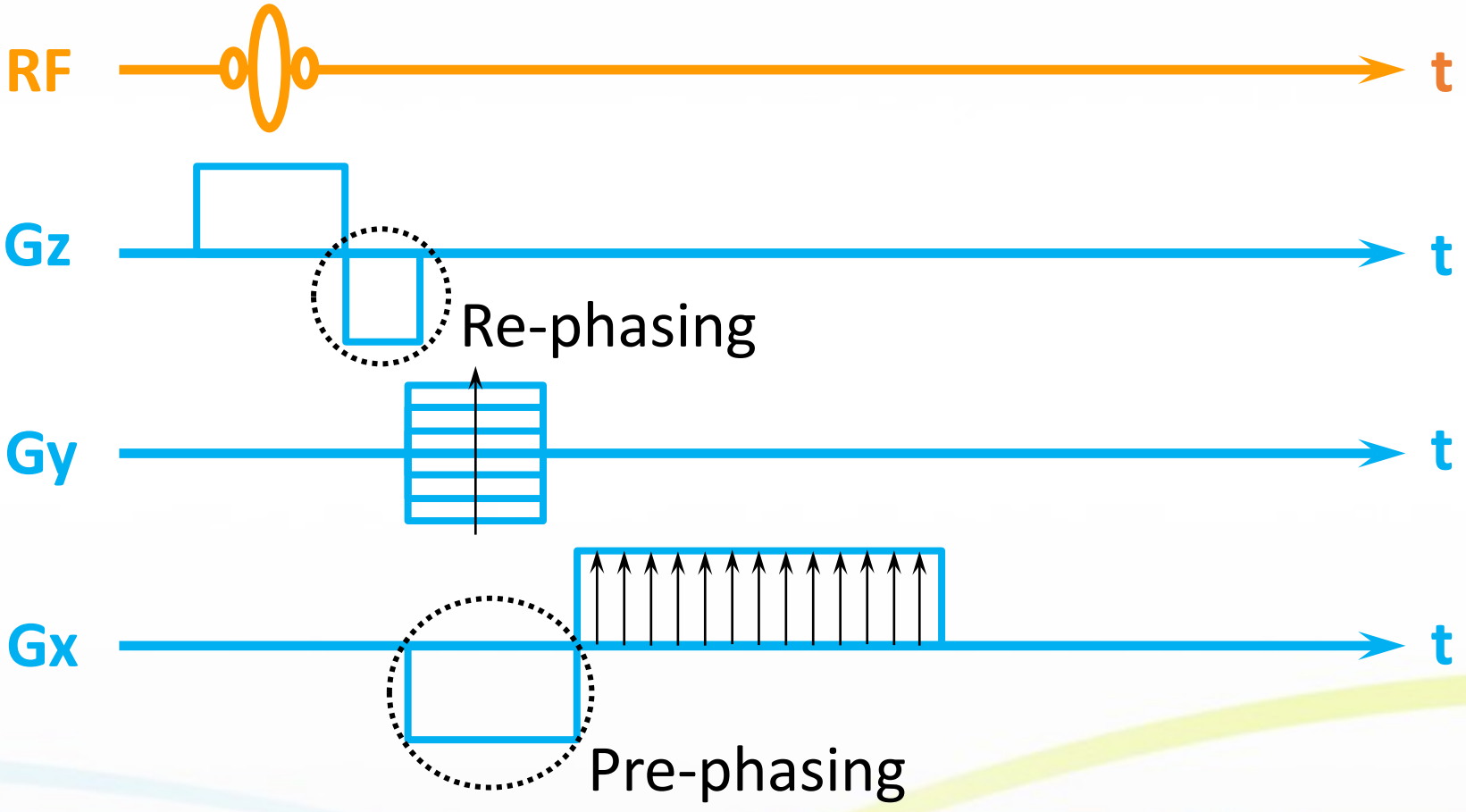
Pulse sequence

- Waveforms of gradients and RF pulses
- All scanning parameters is determined by the waveform
  - Slice selection
  - Phase encoding
  - Frequency encoding

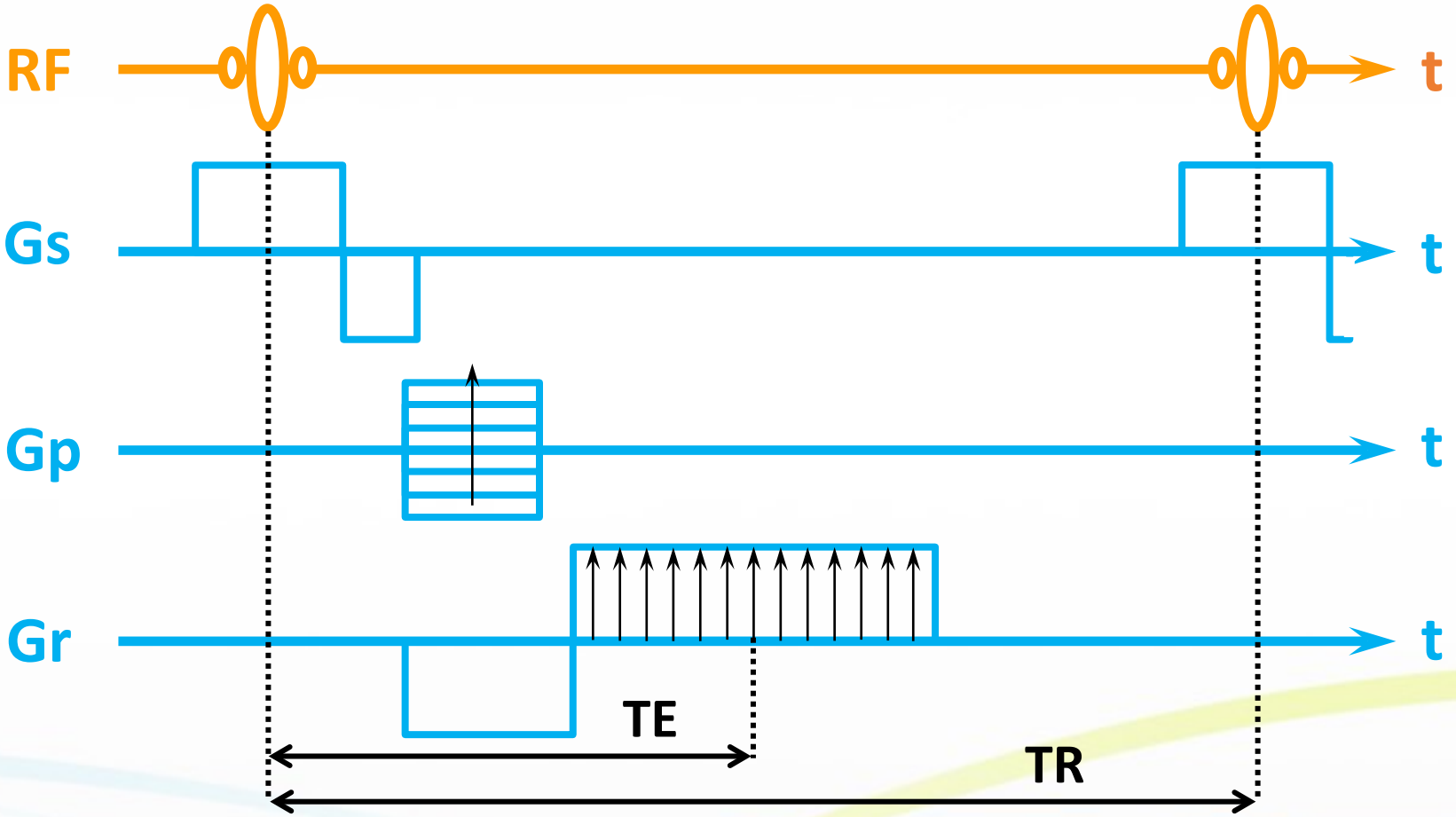
How to determine scan parameters?

- Slice thickness
- Field of view (FOV)
- Pixel width/Matrix size
  - Frequency encoding, or readout encoding
  - Phase encoding

Gradient echo



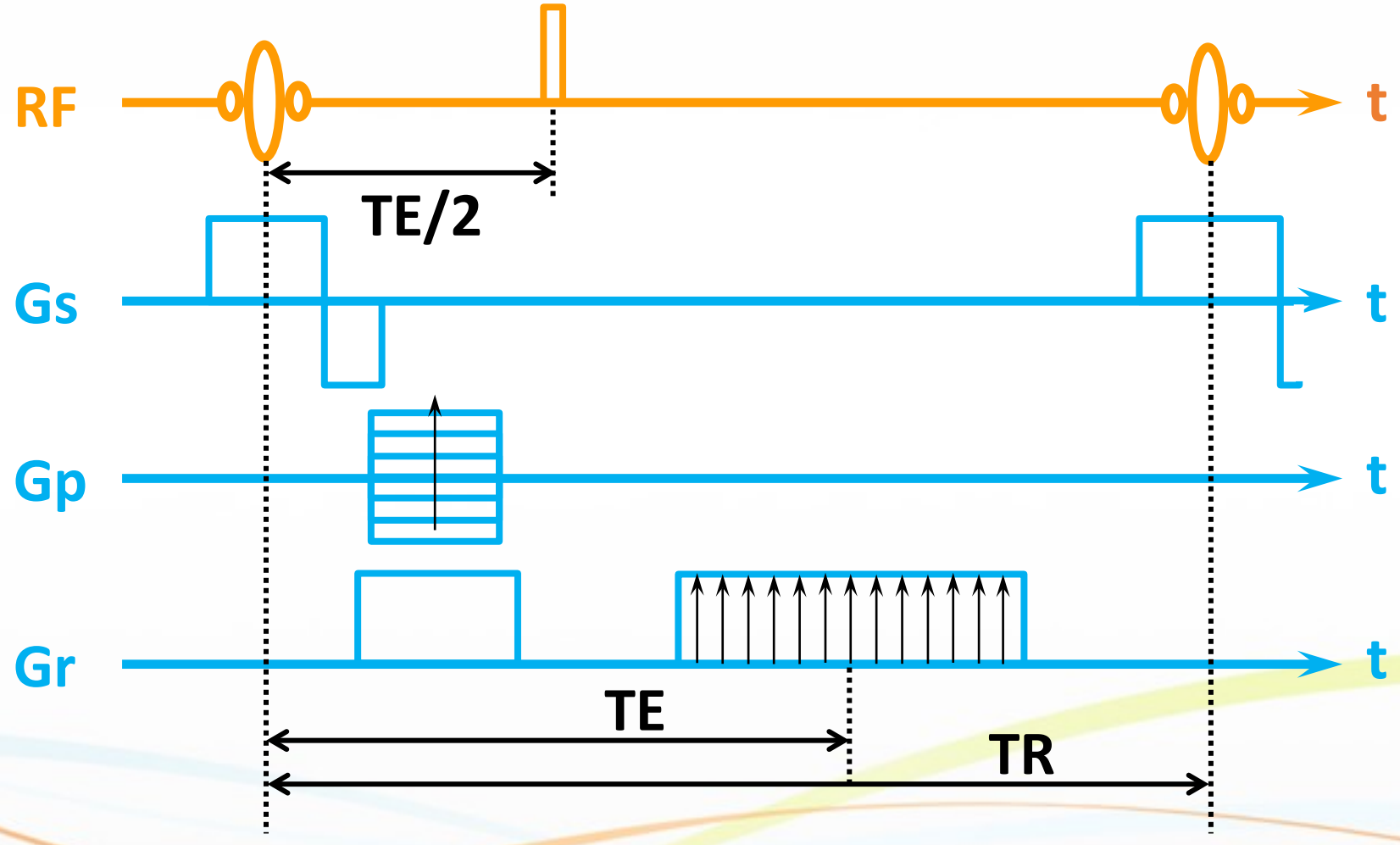
Gradient echo



Gradient echo

- Phase encoding gradient is altered in every TR for sufficient sampling
- Scan time = N_{PE} x TR
- Image contrast is basically determined by TE and TR
- How about spin echo?

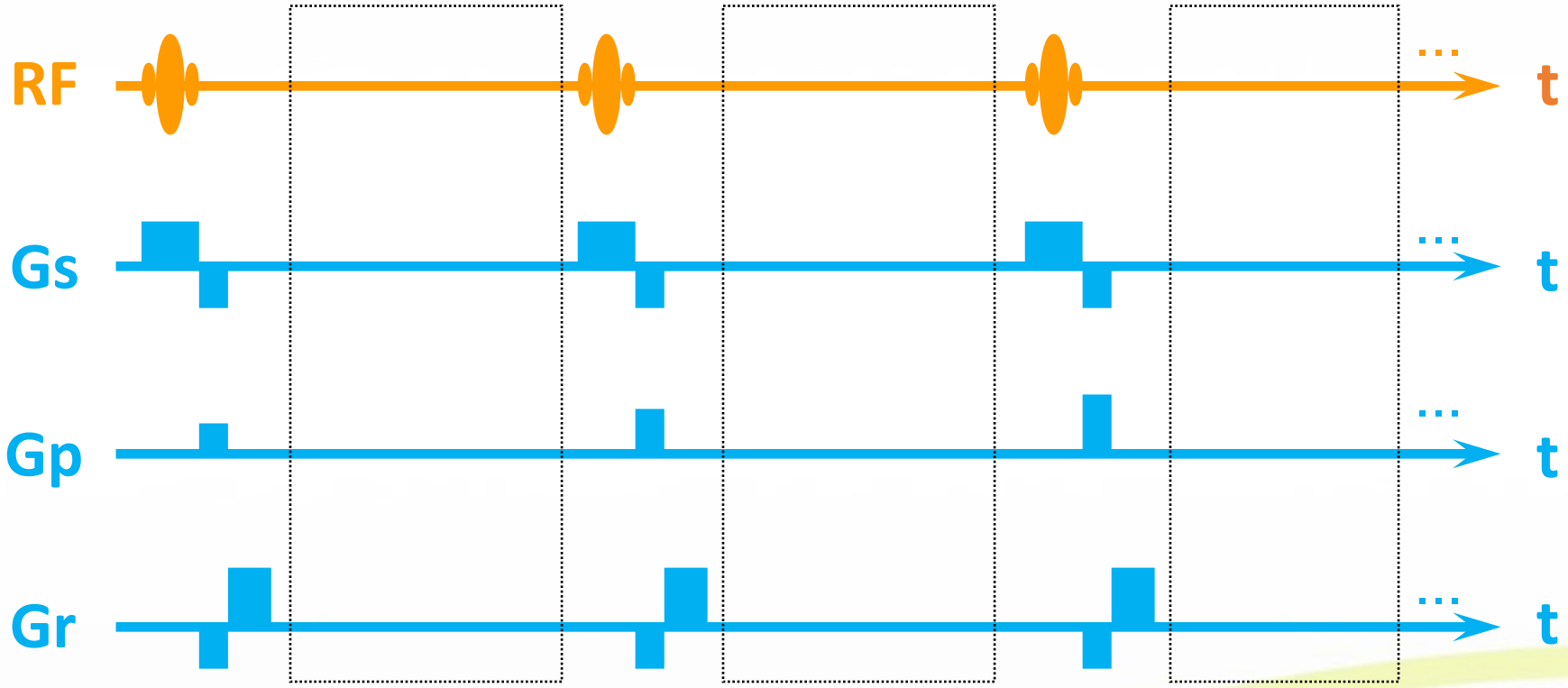
Spin echo



Imaging in 3D space

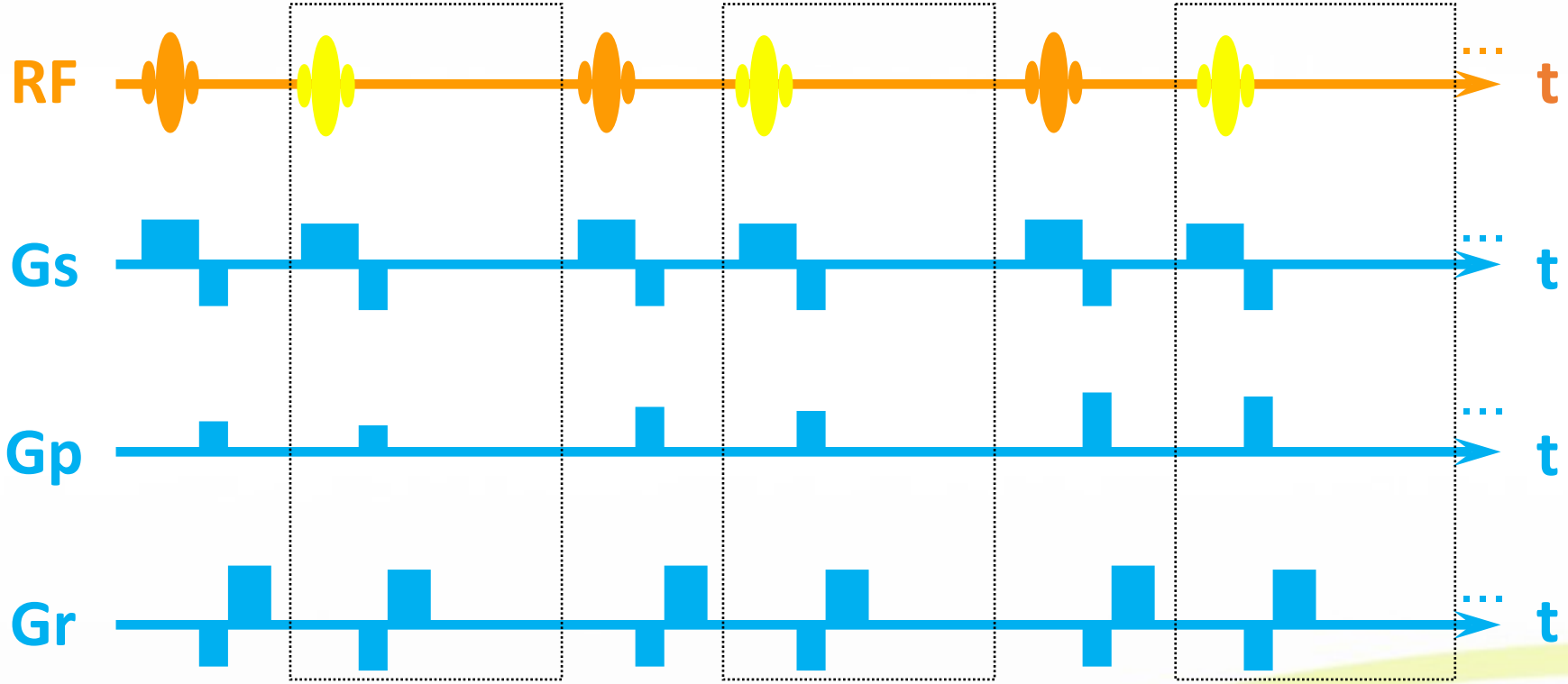
- 2D image suitable for human vision
  - Limited information
- Multi-slice imaging is favored to increase spatial coverage.
- Scan one slice after another?

Pulse sequence of more TR cycles…



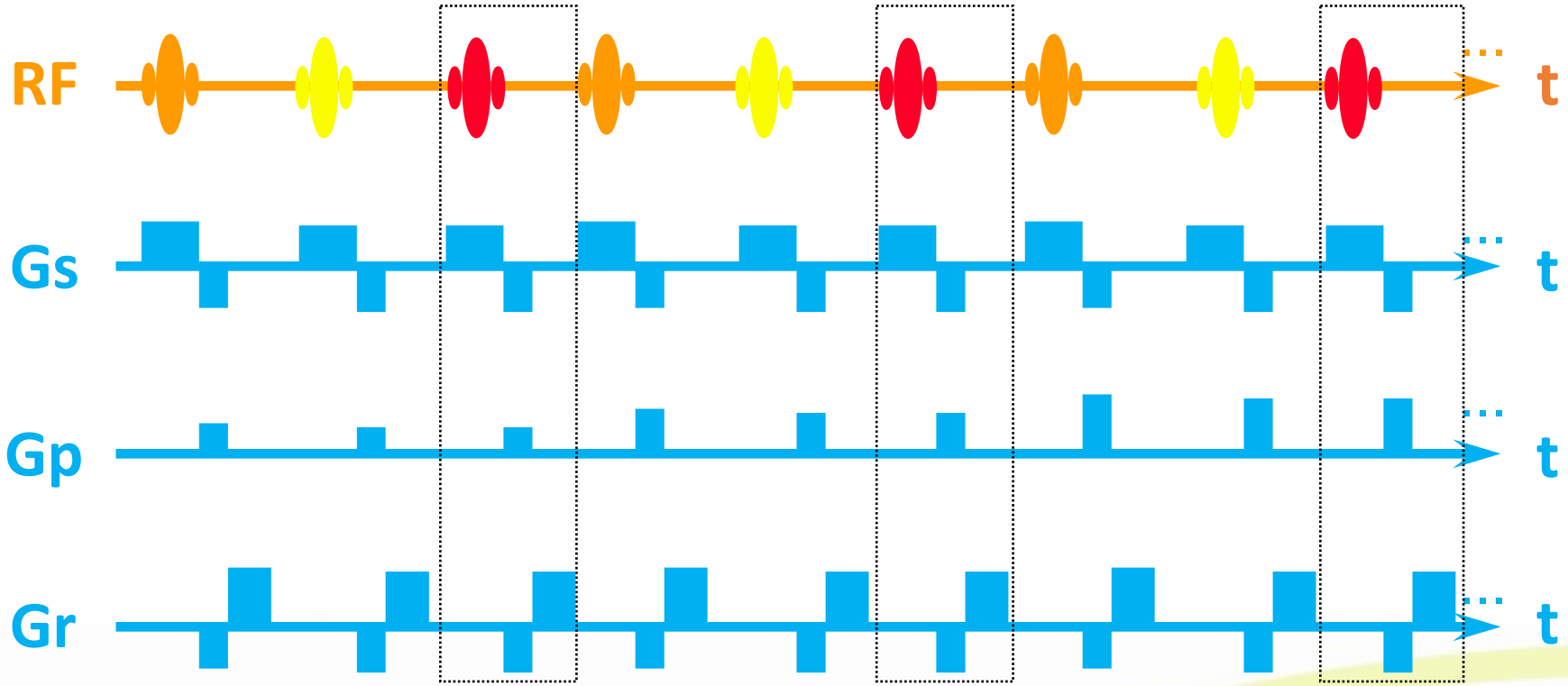
TE >> TR: do nothing for most of time

Insertion of another slice



Taking advantage of the spare time

Insertion of one another slice again



Multi-slice imaging

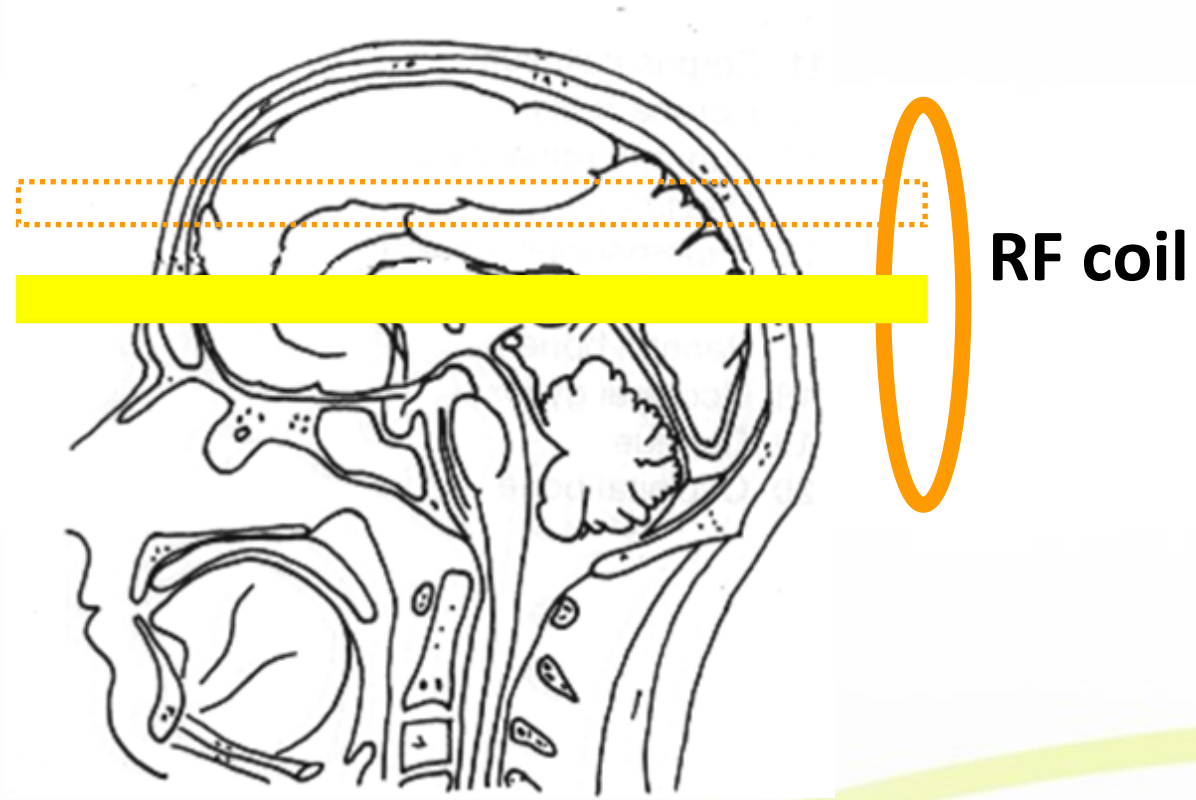
Multi-slice imaging

Multi-slice imaging

Signal induction
and decay

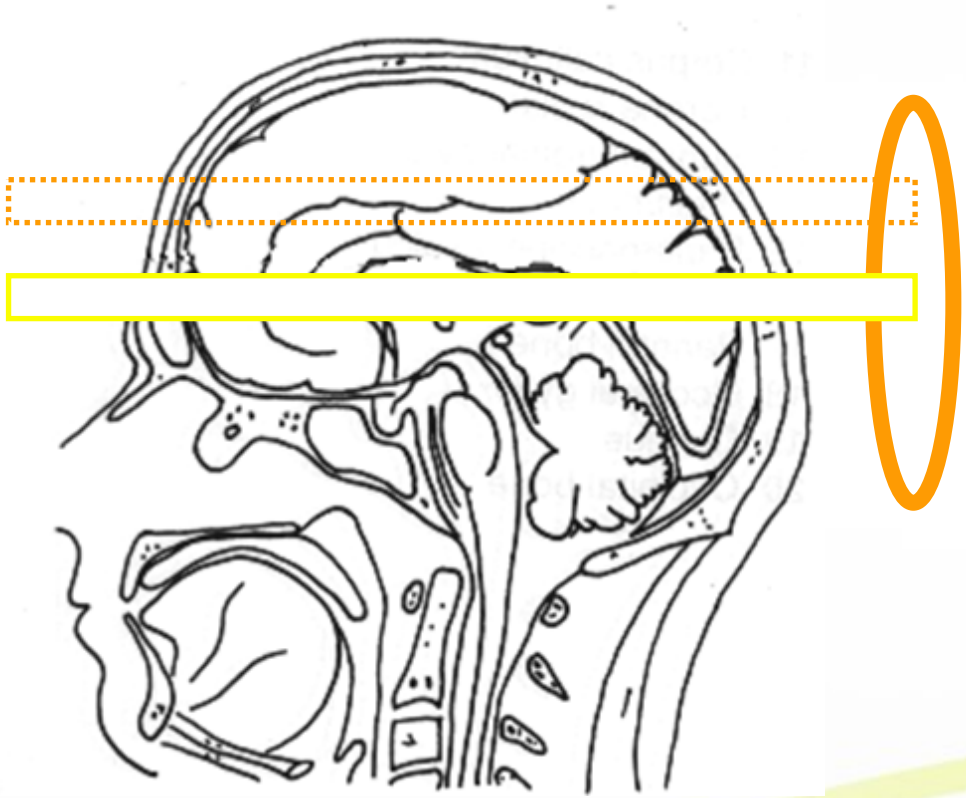
RF coil
Signal reception

Multi-slice imaging



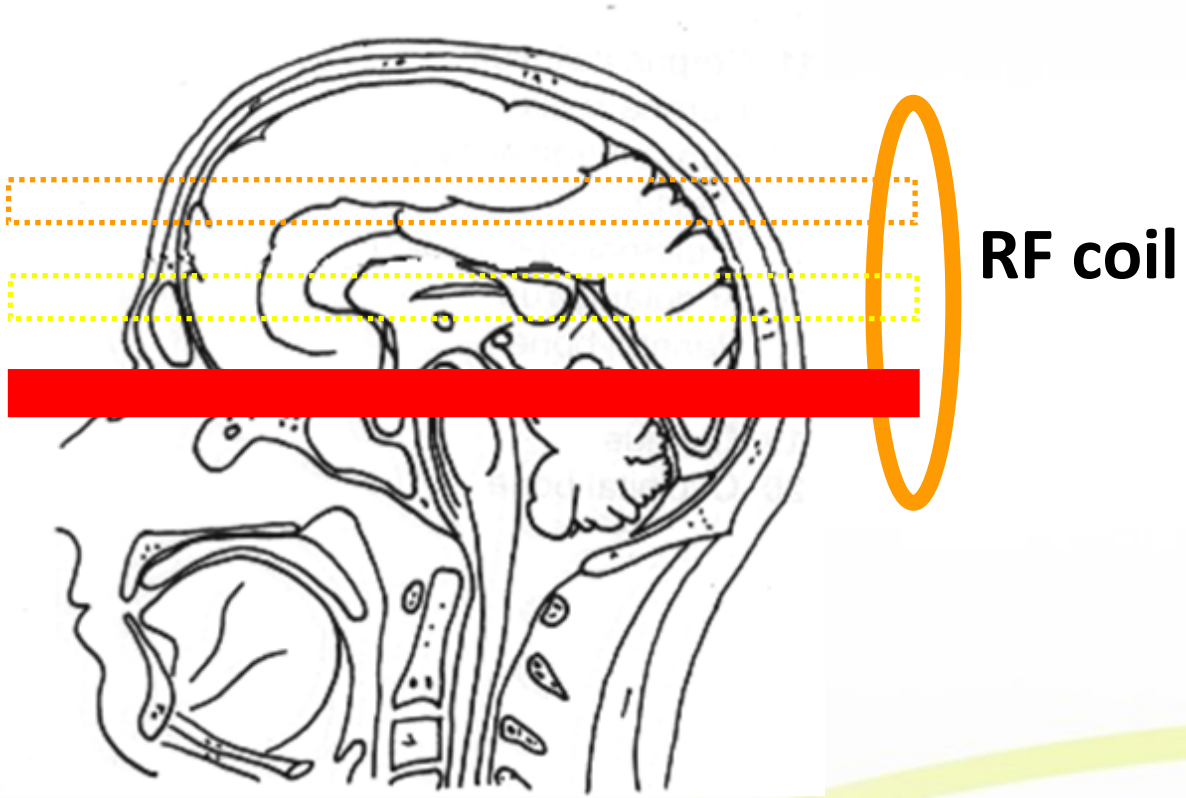
Multi-slice imaging

Signal induction and decay



RF coil
Signal reception

Multi-slice imaging

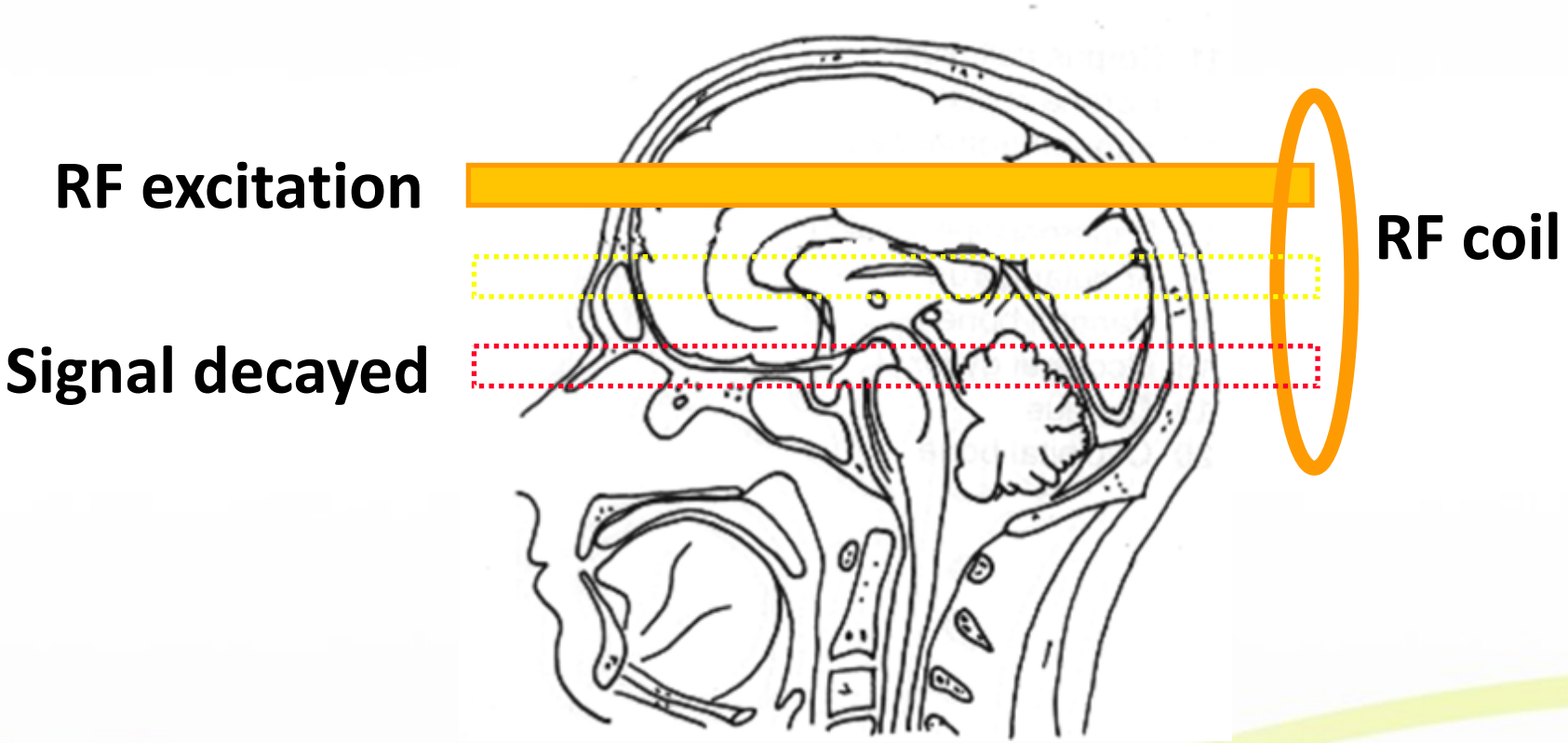


Multi-slice imaging

Signal induction and decay

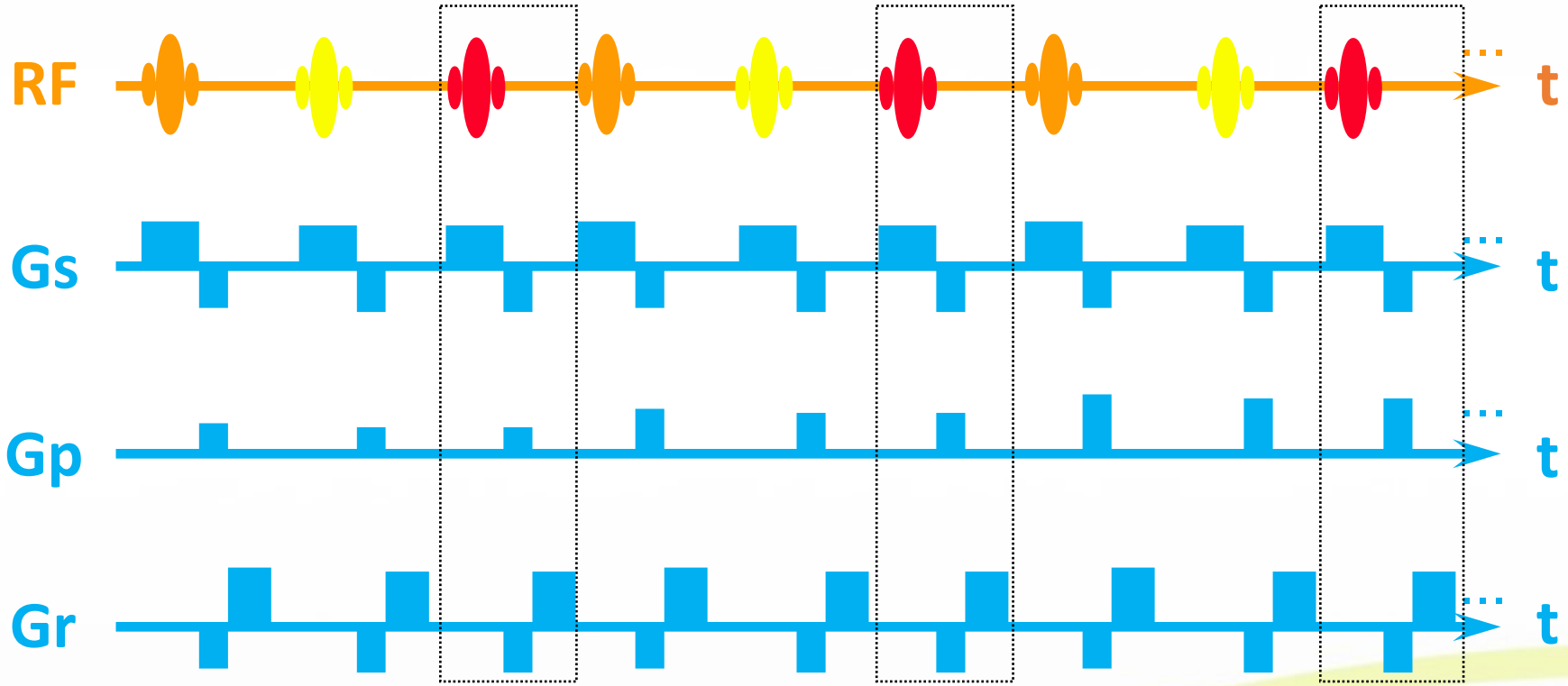
RF coil
Signal reception

Multi-slice imaging



And so on…

Multi-slice pulse sequence

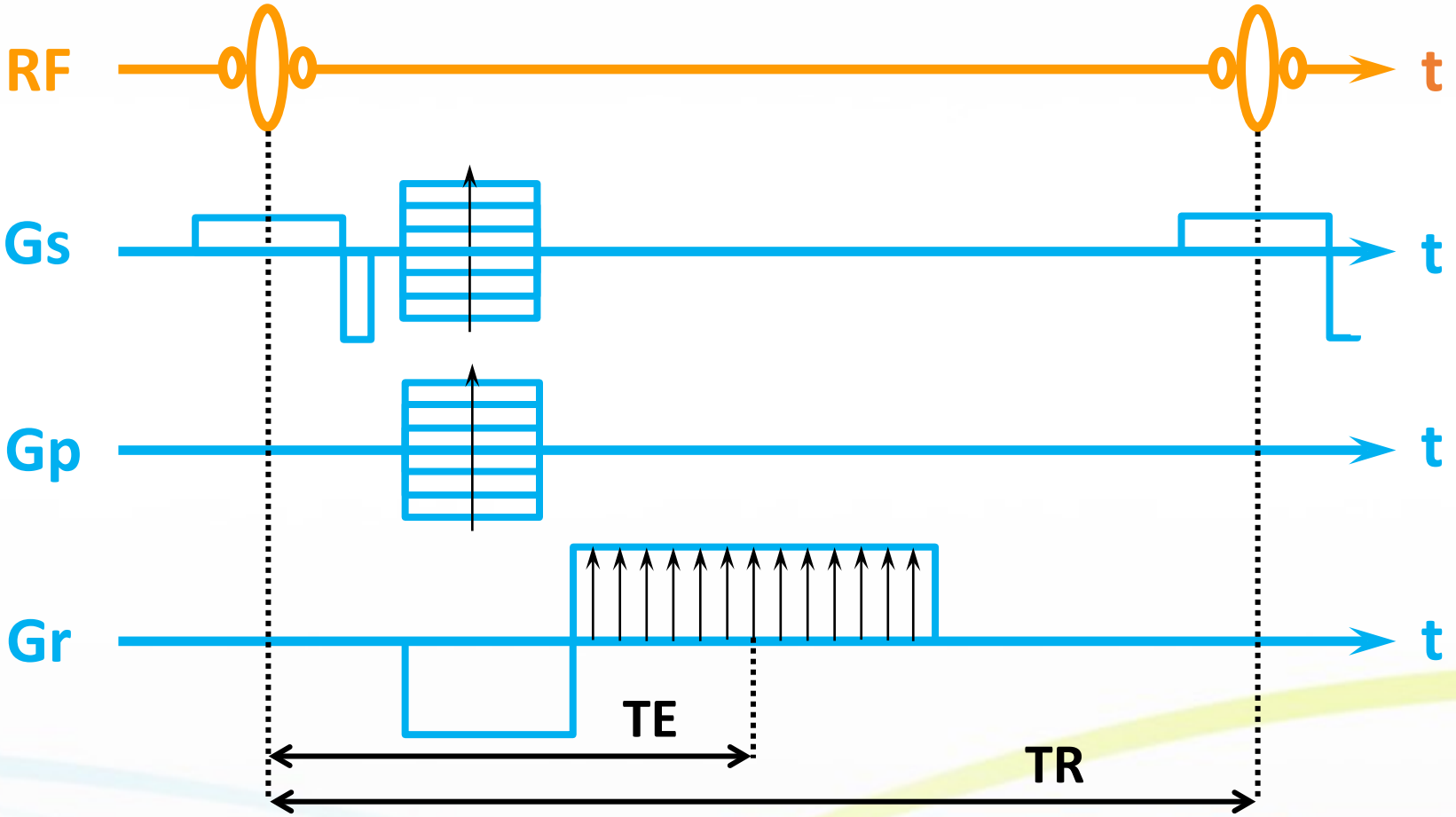


Same total scan time!

3D MRI

- Extend 2D encoding to 3D encoding
- Two sets of independent phase encodings
- 2D-FT → 3D-FT
- No gap between adjacent slices

3D Gradient echo



3D MRI

- Excitation of a thick **slab**
  - Excitation pulse duration can be shortened.
  - So is minimal TE.
  - Only meaningful for ultra-short TE imaging
- Scan time = N_{PE} x N_{SPE} x TR
  - Not practical unless TR is short enough

Basic Principles of MRI